REMARKS

REJECTION OF THE CLAIMS UNDER 35 U.S.C. § 103

Claims 1-3, 5-7 and 9-13 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Tohyama et al. U.S. Patent 5,642,371 in view of Okumura U.S. Patent 6,377,597 for the reasons set forth on pages 2-6 of the Action.

For the reasons set forth hereafter, it is submitted that the claims are patentable over Tohyama et al.

PATENTABILITY OF THE CLAIMS

In rejecting claims 1-3, 5-7 and 9-13 as unpatentable over Tohyama et al. in view of Okumura, the Examiner stated on page 3 that "Tohyama discloses the claimed invention except for multiple quantum well having at least two quaternary mixed crystal layers in which a band offset of conduction band is larger than a band offset of valence electron band, said at least two quaternary mixed crystal layers being selected from the group consisting of quaternary mixed compound of Un, Ga, Al, As and a quaternary mixed compound of Un[In], Ga, N, and As." To allegedly supply the acknowledged deficiency of Tohyama quoted above, the Examiner then cited Okumura as teaching "a multiple quantum well having at least two quaternary mixed crystal layers in which a band offset of conduction band is larger than a band offset of a valence electron band, said at least two quaternary mixed crystal layers being selected from the group consisting of quaternary mixed compounds of In, Ga, Al, and As and a quaternary mixed

compound of Un[In], Ga, N, and As with a module device..." Based on this interpretation of Okumura, the Examiner held that Applicants invention was obvious under 35 U.S.C. § 103(a).

It is submitted, however, that the Examiner has misinterpreted the teachings of both Tohyama et al. and Okumura as discussed hereafter.

It is important to note that all three of independent claims 1, 5 and 11 contain the limitations of:

(1) A semiconductor laser active region having a multiple-quantum well structure having at least two quaternary mixed compound crystal layers in which a band offset of a conduction band is larger than a band offset of a valence electron band.

(2) The quaternary mixed compound crystal layers are selected from the group consisting of quaternary mixed compounds of In, Ga, Al, and As and quaternary mixed compounds of In, Ga, N, and As.

(3) The temperature of a semiconductor laser active region or a temperature of a component in thermal contact with the semiconductor laser active region for holding the temperature of the semiconductor laser active region is set to 35°C or higher during operation of the semiconductor laser active region and the optical modulation region.

With respect to limitation (1) set forth above, the Examiner has acknowledged that Tohyama et al. does not disclose a multiple quantum well having at least two quaternary mixed crystal layers in which a band offset of a conduction band is larger than a band offset of a valence electron band with the two quaternary mixed crystal layers being selected from the group consisting of a quaternary mixed compound of In, Ga, Al and As and a quaternary mixed compound of Un[In]GaN and As. Although the Examiner cited Okumura as teaching this limitation, Applicants believe the Examiner has misinterpreted Okumura in this regard since it is not believed that Okumura teaches having a band offset of a conduction band larger than a band offset of a valence electron band. Indeed, Applicants can find no portion of Okumura which refers to having a band offset of a conduction band larger than a band offset of a valence band. The Examiner has not cited any specific portion of Okumura as teaching this aspect of Applicants invention, but has only broadly stated that Okumura so teaches.

With respect to the limitation (2) above, the Examiner has already acknowledged that Tohyama et al. <u>does not teach</u> at least two quaternary mixed crystal layers selected from the group consisting of a quaternary mixed compound of In, Ga, Al and As and a quaternary mixed compound of Un[In], Ga, N and As.

Okumura et al. also <u>does not teach</u> the use of at least two quaternary mixed crystal layers selected from the group consisting of a quaternary mixed compound of In, Ga, Al and As and a quaternary mixed compound of In, Ga, N and As. The only reference that Applicants can find with respect to quaternary or higher mixed crystal semiconductor layers in Okumura is reference two the quantum well layers and the barrier layer being made from quaternary or higher mixed crystal semiconductor composed of InGaN ternary mixed crystal and, in addition to this, other elements such as Al in trace amounts.

These references are made in column 7, lines 11-15; column 12, lines 8-12; column 14, lines 7-11 and column 17, line 55-column 18, line 2. Thus, the most that it can be said for Okumura is that teaches use of In, Ga, Al and N. The Applicants independent claims, on the other hand, call for In, Ga, Al and As or In, Ga, N and As. Therefore, neither Tohyama nor Okumura meet the limitations of limitation (2) of Applicants independent claims.

Finally, with respect to limitation (3) that the temperature is set to 35°C or higher during operation of the semiconductor laser active region and the optical modulation region, neither Tohyama et al. nor Okumura disclose this limitation.

With respect to Tohyama et al., the Examiner referred to Fig. 28 as showing the temperature of the semiconductor laser active region to be set to 35°C or higher. Fig. 28, however, shows 33°C as the highest temperature achieved by Tohyama et al. A copy of Fig. 28 is attached as Exhibit A. Neither does Okumura teach the 35°C or higher limitation. In fact, the Examiner has not cited Okumura as teaching the 35°C or higher limitation.

As discussed in detail hereafter, the differences between Applicants invention as claimed and the cited Tohyama et al. and Okumura references are significant.

A most important feature of Applicants invention is that a band offset of a conduction band is larger than a band offset of a valence electron band as called for by the independent claims. This feature is illustrated in the marked up copy of Fig. 3 of the present application, attached as Exhibit B.

A reason this feature is important is that, as shown in Fig. 3, the band offset of the conduction band is larger than the band offset of the valence electron band. See the paragraph bridging pages 15 and 16 of the specification. With such a constitution, overflow of an injection current at high temperature can be reduced to suppress the decrease of the optical power at high temperature.

From the viewpoint of the temperature dependence for overflowing of electrons from the conduction band, it is better to make the band offset of the conduction band larger. However, for example, generally in a prior art InGaAsP system, which is currently used for a laser device and a semiconductor module, **a band offset of a valence band becomes larger as a band offset of a conduction band grows larger.**

In either system, InGaA1As or InGaNAs, Applicants' invention makes a band offset of its valence band larger than a band offset of its conduction band.

In the present invention, the semiconductor laser device and the semiconductor electroabsorption optical module are monolithically integrated or formed on the same substrate and they are made of the same material system.

In the case of the prior art InGaAsP system, **a band offset of a valence band becomes larger as a band offset of a conduction band grows larger.** In a semiconductor electro absorption optical module, positive holes are accumulated or piled up in an absorption layer of the semiconductor electroabsorption optical module, and the accumulated positive holes degrade their modulation characteristic.

Therefore, in the case of (1) a module for optical communication having a modulator monolithically integrated laser on the same substrate and (2) the optical modulation region and the semiconductor laser region are made of the same material system and the two regions have the different content ratios of their elements from each other, **it is necessary to**

use not only a larger band offset of a conduction band, but also a smaller band offset of a valence band, as in Applicants' invention, to prevent overflow of injection current at high temperature and to extremely moderate the requirement of cooling the optical modulator in order to obtain a predetermined optical power. See page 10, lines 12-21 and page 10, line 22 to page 11, line 11 of the specification.

The reasons why positive holes are accumulated in an absorption layer of the semiconductor electroabsorption optical module, and why the accumulated positive holes degrade its modulation characteristic in the conventional modulator integrated semiconductor laser device are explained hereafter.

An absorption layer of a semiconductor electroabsorption type optical module region and multiple quantum wells for an active layer of a laser device are usually made of the same material in an integrated optical module, because of easiness of fabricating. It is necessary to use a larger band offset of the conduction band to obtain a good characteristic of the laser device at high temperatures. However, as stated above, the band offset of the valence band becomes larger as a band of a conduction band grows larger. Because of the larger band offset of the valence band, positive holes, which are generated in the absorption layer when the absorption layer of the semiconductor electroabsorption type optical module absorbs incident light, are not pulled out and are accumulated or piled up in the multi-quantum well. The positive holes are

unavoidably generated when an electric signal is converted to an optical signal in this optical module.

Because the effective mass of a positive hole is heavier than that of an electron, if the band offset is the same value between the conduction band and the valence band, the positive holes cannot pass through its barrier and are accumulated or piled up in the multi-quantum well. The accumulated positive holes deform an electric field caused by an electric signal of the optical communication. The electric field caused by the positive holes in the multi-quantum well has a transverse direction to the electric field caused by the electric signal of the optical communication. This effect of the accumulated positive holes is called a "screening effect."

The screening effect caused by accumulated positive holes causes degradation for the optical absorption. Therefore, correct electric waveform cannot be obtained corresponding to an optical signal by this modulator integrated semiconductor laser device.

New dependent claims 15-18 have been added to specifically claim other aspects of Applicants' invention and are believed patentable for the same reasons as set forth above, in addition to the specific matters set forth therein.

For the reasons set forth above, it is submitted that Applicants' claims are patentable over the Tohyama et al. and Okumura references or any other prior art references.

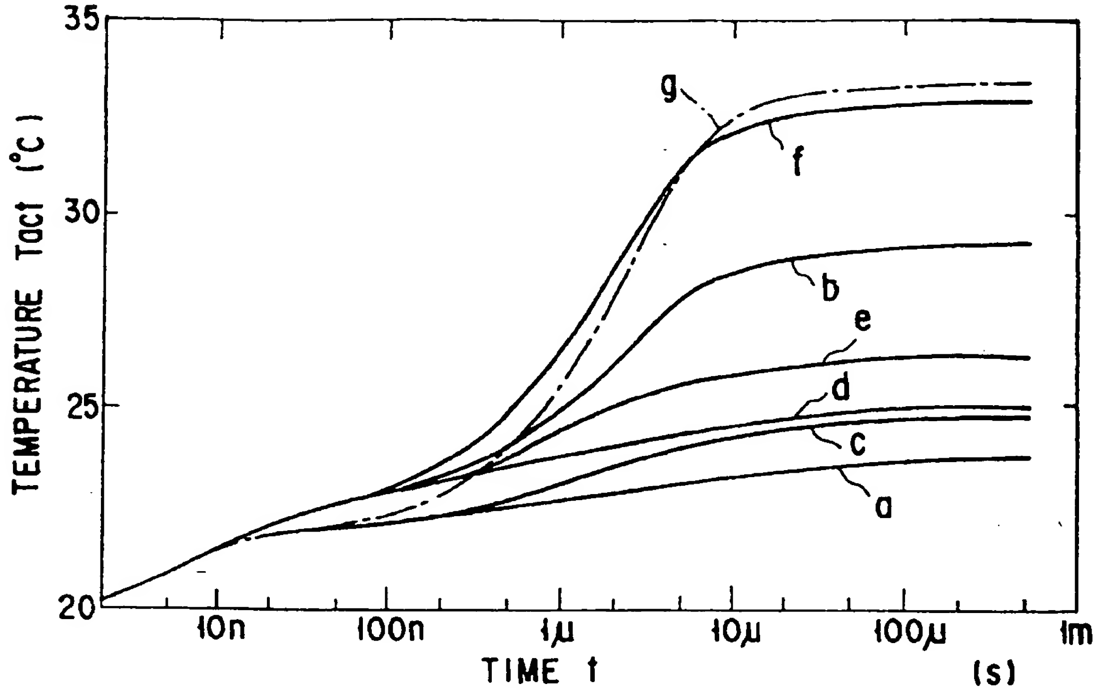
In view of the foregoing amendments and remarks, Applicants contend that this application is in condition for allowance. Accordingly, reconsideration and reexamination are respectfully requested.

Respectfully submitted,

Gene W. Stockman

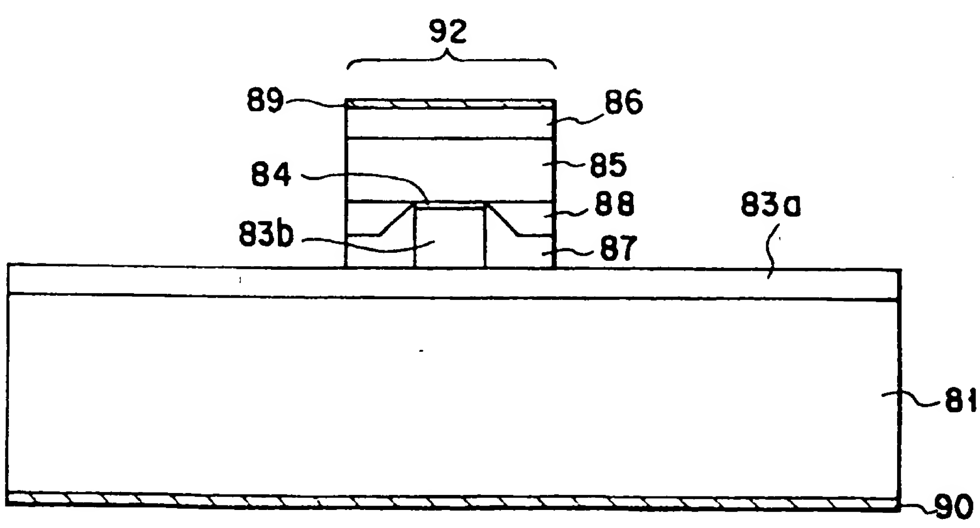
Gene W. Stockman
Registration No. 21,021
Attorney for Applicants

MATTINGLY, STANGER & MALUR
1800 Diagonal Road, Suite 370
Alexandria, Virginia 22314
(703) 684-1120
Date: January 26, 2004



35
30
25
20
TEMPERATURE Tact (°C)
g
f
b
e
d
c
a
10n
100n
1μ
10μ
100μ
1m
TIME t
(s)

F I G. 28



92
89
86
85
84
88
83b
87
83a
81
90

F I G. 29

Sketch

Fig. 3

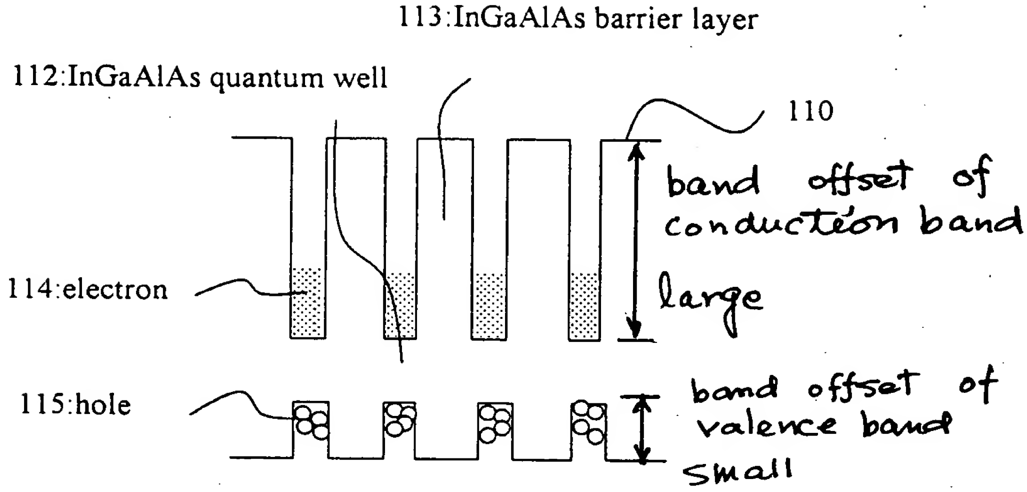


Fig. 4

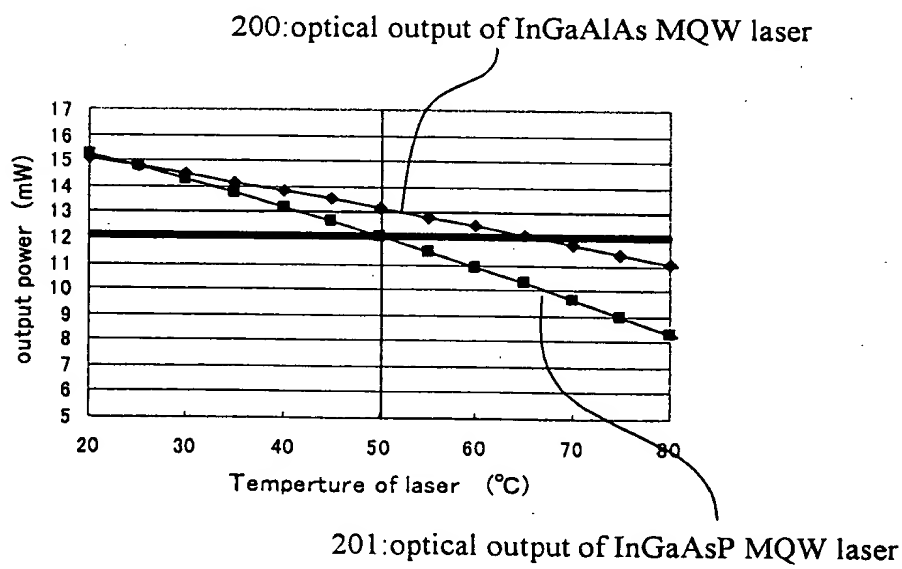


EXHIBIT B